(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : 0 629 963 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number : 94304291.1

(22) Date of filing : 14.06.94

(51) Int. Cl.^{5} : G06F 15/42

(30) Priority : 21.06.93 US 78335

(43) Date of publication of application : 21.12.94 Bulletin 94/51

(84) Designated Contracting States : DE FR NL

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(54) A display system for visualization of body structures during medical procedures.

(57) An interactive display system superimposes radiological images on a semi-transparent screen through which a surgeon views a patient during a medical procedure. The superimposed image is derived from image data obtained with an imaging system. The radiological image is registered with the surgeon's view of the patient and displayed in real-time during a medical procedure. This allows the surgeon to view internal and external structures and the relation between them simultaneously, and adjust the procedure accordingly. A second embodiment employs stereoscopic viewing methods to provide three-dimensional representations of the radiological images superimposed on the semi-transparent screen through which the surgeon views the patient.

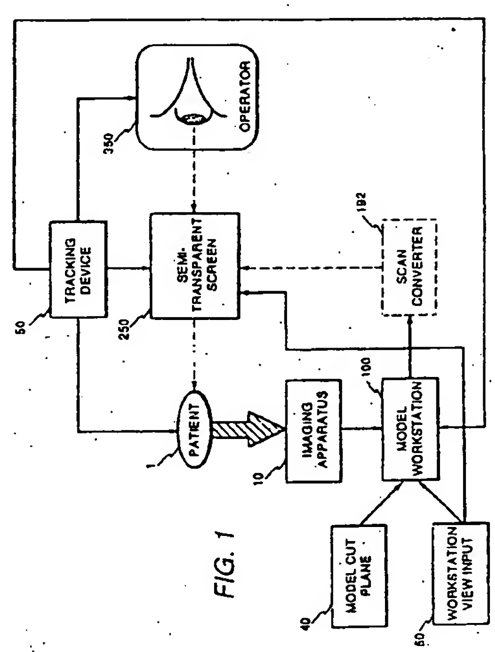

FIG. 1

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monitored in real-time. This information is then used to adapt the computer generated display on the semi-transparent screen so that the visual and computer generated images consistently coincide.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the invention believed to be novel are set forth with particularity in the appended claims. The invention itself, however, both as to organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawing in which:

Fig. 1 is a simplified block diagram of a first embodiment of a medical display apparatus according to the present invention.

Fig. 2 is a simplified block diagram of a second embodiment of a medical display apparatus according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In Fig. 1, a patient 1 on which a medical procedure such as surgery is to be performed, is scanned by a medical imaging apparatus 10 which may be a magnetic resonance (MR) imaging apparatus, a computed axial tomography (CAT) apparatus, a positron emission tomography (PET) or similar imaging device capable of creating multi-dimensional volumetric data such as 3-dimensional (3-D) data, from internal structures of the patient. After imaging, apparatus 10 provides the volumetric data to a model workstation 100. Once the volumetric data has been provided to model workstation 100, further need for imaging apparatus 10 imaging apparatus is no longer required. This is important since some medical procedures need not be performed with the patient situated within the confines of an imaging apparatus, which can be constricting in the case of MR imaging. In alternative embodiments, imaging apparatus 10 may be interactively employed during the medical procedure. Model workstation 100 stores the volumetric data and creates computer generated models from the data capable of being scaled, rotated and otherwise manipulated, without the further need for imaging apparatus 10.

An operator 350, such as a physician or medical assistant, monitors patient 1. A semi-transparent screen 250 is interposed between patient 1 and operator 350. A tracking device 50 which monitors and tracks operator 350, semi-transparent screen 250 and patient 1 determines a relative roll α, pitch θ, and yaw ϕ orientation between operator 350, semi-transparent screen 250 and subject 1. Tracking device 50 may be a 6-degrees of freedom tracking device as described "The Flock of Birds" Installation and Operation Guide, Ascension Technology Corporation, July 5, 1992, in the Introduction pp. 1-3, Appendix 1, p. 89 and Appendix 3, p. 93. Tracking device 50 also determines a location (in Cartesian coordinates) of operator 350 and semi-transparent screen 250 with relation to patient 1. Patient 1 is assumed to be at the origin of the Cartesian coordinate system (x,y,z) = (0,0,0), therefore all distances relative to the patient are simply the (x,y,z) location. The location and orientation are interactively provided to model workstation 100 by tracking device 50. The location and orientation may also be provided manually to model workstation(s) in different embodiments.

Model workstation 100 processes the 3D volumetric data it receives and creates selected renderings of the data. One rendering method determines surfaces between differing types of tissue. Connectivity of similar types of tissue adjacent to one another is then determined. Differentiation of tissue types based on the nature of the signal in the three-dimensional image data is known as segmentation. When the 3-D volumetric data has been segmented into internal structures, each internal structure may be treated as a separate solid object by model workstation 100. The model workstation has the capability of selectively displaying desired internal structures, color coding structures and severing, rotating and translating internal structures in order to manipulate these images in a desired manner to provide visualization to an operator working model workstation 100.

An alternative rendering method generates two-dimensional projections of selected features within the three-dimensional data set is described in European Patent Application 0506302 "Projection Methods for Producing Two-Dimensional Images from Three-Dimensional Data". For example, two-dimensional projection angiograms can be extracted from a three-dimensional phase contrast or time-of-flight magnetic resonance angiogram. Several projection algorithms are possible. These include the detection of the maximum pixel intensity along a selected projection ray through the three-dimensional data, determination of the average pixel intensity of a selected projection ray and the determination of the standard deviation of all pixels along a selected projection ray.

Model workstation 100 receives input data from a model cut plane input device 40 and a workstation view input device 60 to select the method of displaying internal structures of patient 1. Model cut plane input device 40 and a workstation view input device 60 may be a computer pointing device such as a mouse or trackball, or any input device which indicates planes in which to cut the images and a viewing angle and scale. Tracking device 50 provides relative orientation data between operator 350 and patient 1 and scaling, which allows model workstation 100 to synthesize an interactive computer generated image of internal structures of patient 1 and have it coincide

segmented into what resembles a solid object, it may be manipulated as a solid object. In the case of structures of a patient, a surgeon may acquire data from the patient by medical imaging, then plan surgery by manipulating the models to plan a desired result before surgery. This is common in complex reconstructive surgery. Once the plan is determined, it may be stored and played back during surgery. The images of internal structures are interactively oriented and scaled to coincide with the actual patient.

A user employs as a model cut plane input device, a workstation view input device (40, 60 of Figs. 1 and 2, respectively) to select planes in which to cut the structures in the model, to select a three-dimensional orientation of the model, and to select screen cut planes which define a workstation viewing region. The model workstation can incorporate a clipping circuit to determine points within the model cut planes, a rotation circuit to rotate points and normal vectors, a segmentation processor, and a shading circuit which determines shading based upon the orientation of the normal vector at each point. In addition a screen clipping circuit can be used to determine points within a region defined by the screen cut planes. The model workstation also can include a display circuit to create video signals which, when propagated to a suitable display device, generate images of multiple surfaces that are within the desired display region and the screen cut planes.

In radical surgery such as ablative surgery, or massive trauma cases, there is little structure which remains to correctly determine what a normal anatomy should be. In these cases, an additional model workstation may have a model of normal structures stored which may be mixed with the other images being displayed to act as a guide in reconstructive surgery. This may be implemented by additional workstations or model manipulation boards.

In the present embodiments of the invention, semi-transparent screen 250 is interposed between operator 350 and patient 1. Screen 250 can be constructed with a liquid crystal display or it can be comprised of a partially silvered mirror reflecting an image from a video monitor. Semi-transparent display 250 can be constructed as a relatively large device having dimensions approximately equal to that of the region of interest of patient 1, or alternatively it can be of small dimension and placed relatively close to the operator's eyes, perhaps incorporated into headgear or eyewear.

While several presently preferred embodiments of the novel visualization system have been described in detail herein, many modifications and variations will now become apparent to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and variations

Claims

1. A real-time medical apparatus for displaying to an operator interactive images of internal structures of a patient coinciding with a view by the operator of the patient comprising:
   a) a medical imaging system for obtaining multi-dimensional imaging data of internal structures of said patient;
   b) a workstation for creating images from the imaging data of internal structures of said patient viewed from a location (x,y,z) and orientation (α,ϕ,θ) which coincide with said view of the patient by said operator;
   c) a semi-transparent screen adapted for allowing said operator to view said patient through the semi-transparent screen and adapted for displaying the images of internal structures from the workstation with a desired degree of transparency to create the illusion of internal structures superimposed upon said patient.

2. The real-time medical apparatus of claim 1 further comprising a tracking device adapted to measure the location (x,y,z) and orientation (α,ϕ,θ) of said operator with respect to said patient, for repeatedly providing these measurements to the workstation.

3. The real-time medical apparatus of claim 1 wherein the workstation further comprises surgical planning means adapted to create models of internal structures of said patient, interactively manipulate the models to result in modifications to internal structures, store the models and modifications and display the models and modifications viewed from a location and orientation to coincide with the view of the patient by the operator.

4. The real-time medical apparatus of claim 1 wherein the workstation incorporates normal anatomical models of internal structures, and is adapted to display the models viewed from a location and orientation to coincide with the view of the patient by the operator, such that said workstation can act as a guide in reconstructive surgery.

5. A real-time medical apparatus for displaying to an operator interactive three-dimensional (3D) internal and external images of a patient comprising:
   a) a medical imaging system for obtaining three-dimensional (3D) imaging data of internal structures of said patient;
   b) tracking means for measuring locations (x_1,y_1,z_1) (x_2,y_2,z_2) and orientation angles (α_1,ϕ_1,θ_1) (α_2,ϕ_2,θ_2) of each eye of said opera-

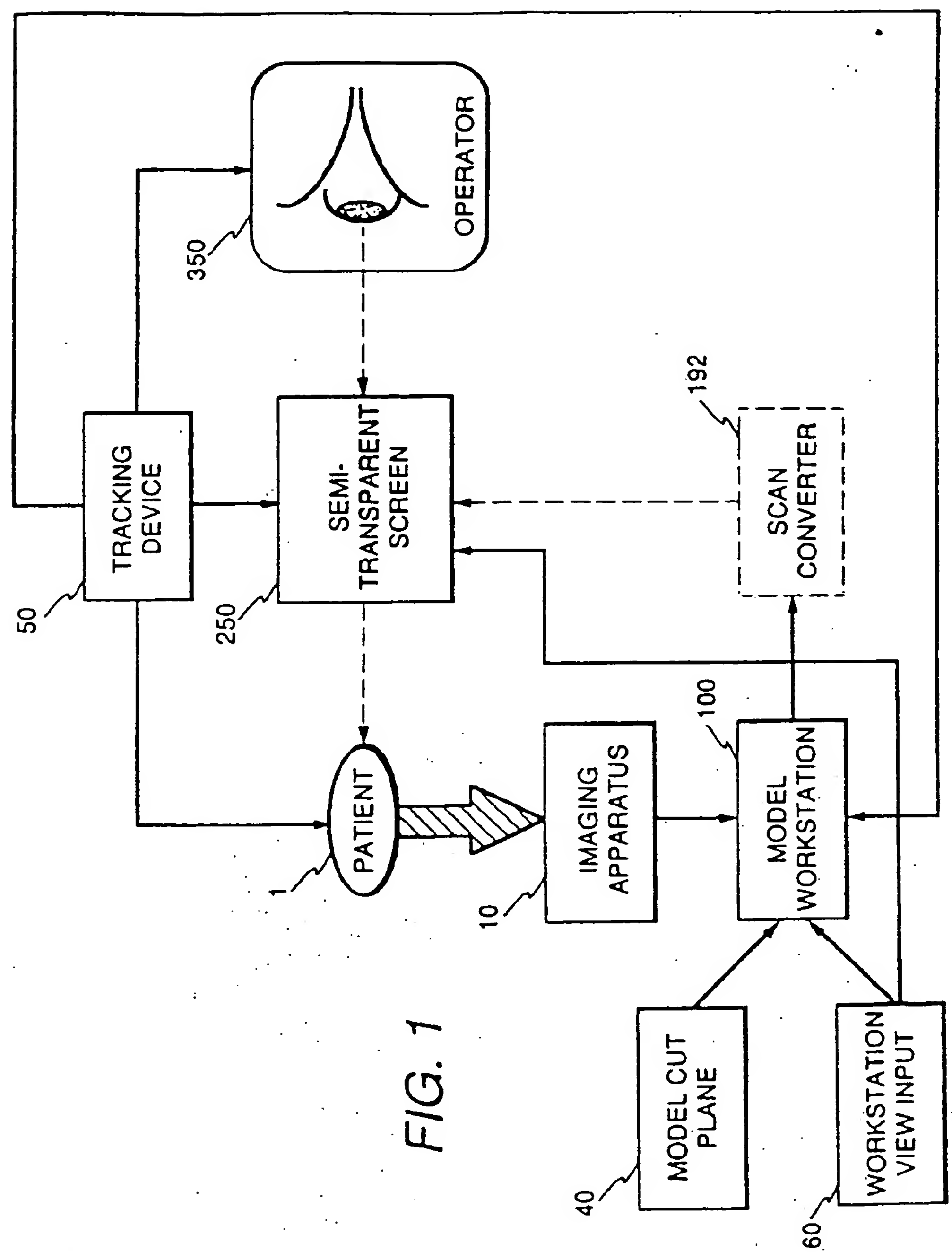
OPERATOR
350
TRACKING DEVICE
50
SEMI-TRANSPARENT SCREEN
250
SCAN CONVERTER
192
PATIENT
1
IMAGING APPARATUS
10
MODEL WORKSTATION
100
MODEL CUT PLANE
40
WORKSTATION VIEW INPUT
60

FIG. 1

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 4291

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
D,Y	IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, JUNE 1989, USA, vol. 36, no. 6, ISSN 0018-9294, pages 608-617, FRIETS E M ET AL 'A frameless stereotaxic operating microscope for neurosurgery' * page 609, left column, line 10 - page 610, right column, line 32 *	1,2,5,6, 8,9	A61B19/00 G06F15/42
Y	PROCEEDINGS OF THE FIRST CONFERENCE ON VISUALIZATION IN BIOMEDICAL COMPUTING (CAT. NO.90TH0311-1), ATLANTA, GA, USA, 22-25 MAY 1990, ISBN 0-8186-2039-0, 1990, LOS ALAMITOS, CA, USA, IEEE COMPUT. SOC. PRESS, USA, pages 490-497, MILLS P H ET AL '3D ultrasound display using optical tracking' * page 491, right column, paragraph 1.4 *	1,2,5,6, 8,9	
A	PROCEEDINGS OF THE ANNUAL SYMPOSIUM ON COMPUTER BASED MEDICAL SYSTE, DURHAM, JUNE 14 - 17, 1992, no. SYMP. 5, 14 June 1992 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 612-615, XP 000308335 WREDER K ET AL 'STEREOTACTIC SURGICAL PLANNING USING THREE DIMENSIONAL RECONSTRUCTION AND ARTIFICIAL NEURAL NETWORKS' * page 613, line 20 - page 614, line 4 *	1,4,6,8	TECHNICAL FIELDS SEARCHED (Int.Cl.5) A61B G06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28 November 1995	Fournier, C

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document